



MANPRINT SOLDIER SURVIVABILITY PERSPECTIVES

Presented to:
**MANPRINT PRACTITIONERS' WORKSHOP 17-19
August 2004**

By
Rich Zigler



**U.S. Army Research Laboratory
Survivability/Lethality Analysis Directorate
ATTN: AMSRD-ARL-SL-BE
Aberdeen Proving Ground, Maryland 21005-5000**

DSN 298-8625 / 410-278-8625
Email: rzigler@arl.army.mil

[http://www.arl.army.mil/
slad/](http://www.arl.army.mil/slad/)



SOLDIER SURVIVABILITY **IS ON THEIR MINDS**





SIX COMPONENTS OF U.S. ARMY MANPRINT SOLDIER SURVIVABILITY



**ARL-
SLAD**

- **Reduce Fratricide**
- **Reduce Detectability of the Soldier**
- **Reduce Probability of Being Attacked**
- **Minimize Damage**

**ARL-
HRED**

- **Minimize Injury**
- **Reduce Physical and Mental Fatigue**



EXAMPLE OF DESIGN TRADE-OFFS

SAFETY - HUMAN FACTORS - SURVIVABILITY





SURVIVABILITY ANALYSIS CONSIDERATIONS



NATURAL ENVIRONMENT

WEATHER
TEMPERATURE
PRECIPITATION
WIND SPEED
SOLAR RADIATION
VISIBILITY
NIGHT/ILLUMINATION
TERRAIN
GRADE
SURFACE
CHARACTERISTICS
VEGETATION
ALTITUDE
FLORA AND FAUNA
WATER
ENDEMIC DISEASES

MISSION

OFFENSE
DEFENSE
PEACE KEEPING
COUNTER TERRORIST
GROUND
AIRBORNE
AMPHIBIOUS
LONG RANGE RECON
SPECIAL FORCES
MOBILITY

MILITARY ENVIRONMENT

BLAST/OVERPRESSURE
PROJECTILES
FLAME/INCENDIARY
DIRECTED ENERGY
ELECTROMAGNETIC FIELDS
OBSCURANTS
NUCLEAR RADIATION
BIOLOGICAL
CHEMICAL
SOUND
VIBRATION

**SURVIVABILITY
ANALYSIS
CONSIDERATIONS**

PSYCHOLOGICAL

MENTAL STATE
MOTIVATION
VIGILANCE
PSYCHOMOTOR
ISOLATION
COMMUNICATION
TRAINING

PROTECTION

CLOTHING
EQUIPMENT
WEAPONS*
INTERCHANGEABILITY
INTELLIGENCE
MEDICAL ASSISTANCE
LOGISTIC SUPPORT
ADEQUATE FORCES
MAN/MACHINE INTERFACING

PHYSIOLOGICAL

FITNESS STATE
HYDRATION STATE
NUTRITIONAL STATE
SLEEP DEBT STATUS
THERMAL STATE
FATIGUE STATE
DEGRADATION
FACTORS
HUMAN FACTORS
VISION



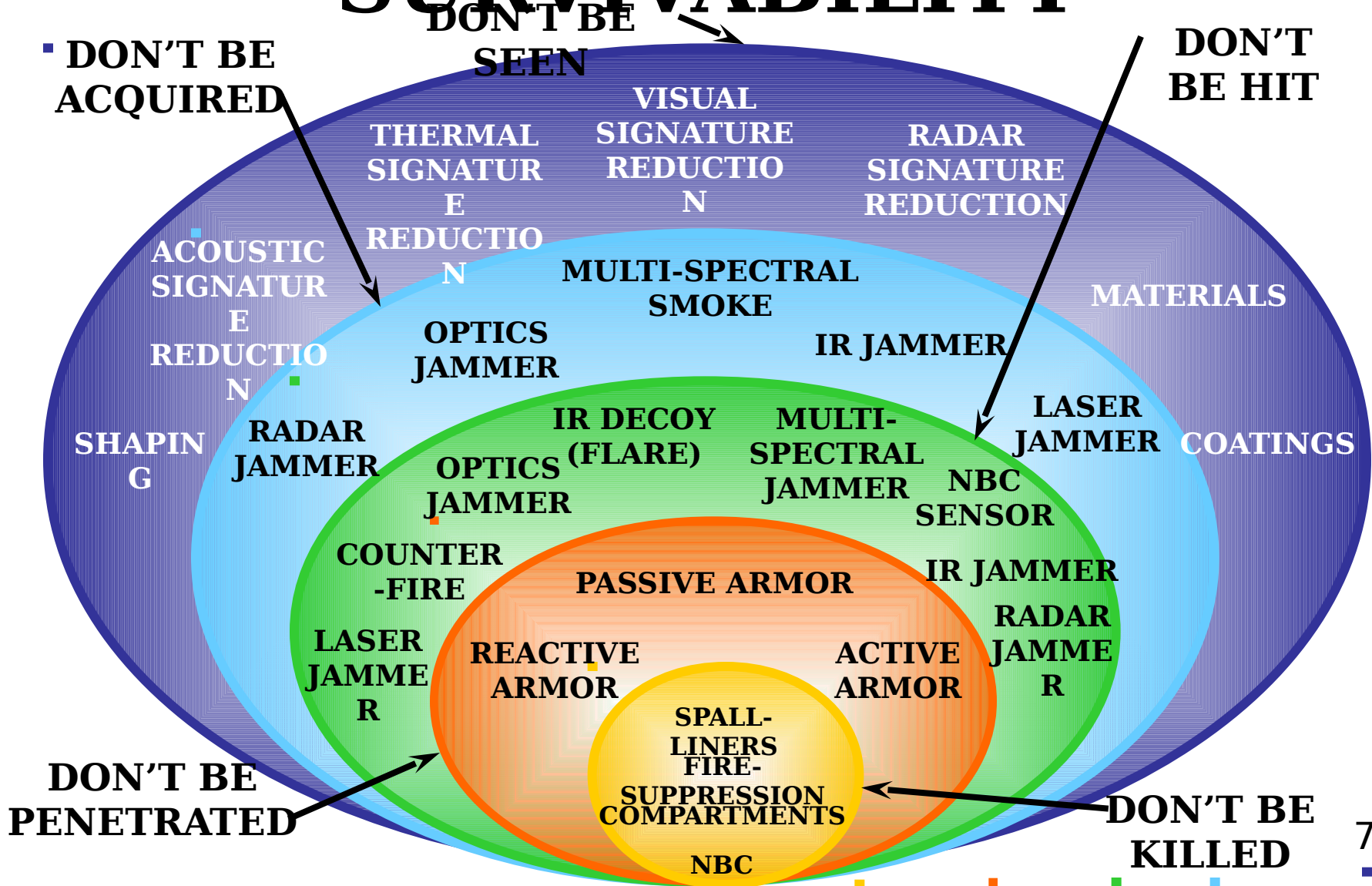
ARMY THREAT CONSIDERATIONS



Image Intensification (III)	Infrared Scopes	Thermal Weapon Sights
Image Intensification (II)	FLIRs	Laser Detection
Laser Blinding	Tunable Lasers	Laser Destruction
Radio Frequency Detection	RF Jamming	RF Destruction
Graphite Smoke	Fuel Oil Smoke	Infrared Smoke
Dust	Phosphorous Smoke	MMW Smoke
Infrared Chaff	Millimeter Wave Chaff	Infrared Flares
Visible Flares	Clutter	Radar
Robotic Mines	Non-Lethal Weapons	Acoustic (Low
Frequency)		
Acoustic Mind Control	Computer Viruses	Malicious Code
Computer Worms	Unmanned Aerial Vehicles	Armored Fighting
Vehicles		
Machine Guns	Pistols	Rifles
Nerve Agents	Blister Agents	Nuclear-Biological-
Chemical		
Electromagnetic Pulse	Bombs	Mines



SYSTEM SURVIVABILITY





SOLDIER SURVIVABILITY



PAL ISSUE EXAMPLES

- **Is the System Able to Deflect Attack by the Use of Electronic Jamming or Spoofing of a Munition's Sensors?**
- **Is the System Able to Deflect Attack by the Use of Active Ballistic Interdiction to Deflect or Destroy Incoming Munitions?**
- **Has any Microprocessor Code on the System been Protected From the Presence or Insertion of Malicious Code ("Back-Doors," Viruses, etc.)?**
- **Does the System Carry Anything Other Than Ammunition That Could Be **Volatile** or Toxic in Combat Situations?**



SOLDIER SURVIVABILITY PAL & **SME** ISSUE EXAMPLES



- Does the System Adequately Protect the Crew From Direct and Indirect-Fire Munitions Through the Specific Damage Mechanism of Spall?
- Does the System Provide Crew Protection From Secondary Explosions of On-Board Munitions if the System Is Attacked, by Means of Separation of Ammunition Storage in a Compartment Isolated From the Crew?
- Does the System Provide Adequate Warning and Protection for the Crew in a Chemically- or Biologically-Contaminated Environment?
- Will a **Buckled Chin-Strap** of a Helmet Create a Potential Hazard in Contributing to Broken Necks in the Presence of Artillery and Mortar Bombardment? (“Wound Ballistics,” U.S. Army Medical Department, 1962, p. 644, per North Africa 1943.)



I. REDUCE FRATRICIDE



U.S. FRATRICIDE RATES OF 20TH CENTURY



CONFLICT	SOURCE OF DATA	FRATRICIDE RATE (Combat Casualties)
World War I	Besecker Diary (Europe)	10% Wounded in Action
World War II	Hopkins New Georgia Burma Bougainville Study	14% Total Casualties 14% Total Casualties 12% WIA; 16% KIA
Korea	25 th Infantry Division	7% Total Casualties
Viet Nam	WDMET* (Autopsy) WDMET Hawkins	14% KIA (Rifle) 11% KIA (Fragments) 11% Casualties 14% Casualties
Just Cause	US DoD	5-12% WIA; 13% KIA
Desert Storm	US DoD	15% WIA; 24% KIA

of "Dead Realistically With Fratricide" by Kenneth K. Steinweg, Parameters, US Army War College, Quarterly, VOL. XXV No.1, Spring 1995, Carlisle Barracks, Carlisle, PA 17013-5050, ph. 717-245-4943

Desert Storm Wounds Data and Study on Ins Effectiveness in Vietnam War (1967-1969)



THERMAL WEAPON SIGHT MARKINGS

THERMAL ID MARKINGS - "COLD THERMAL SIGNATURE"





DOESN'T ALWAYS WORK



**USMC COBRA ATTACK HELICOPTER VS USMC M1A1
ABRAMS TANK**



FRIENDLY FIRE CAN STILL OCCUR



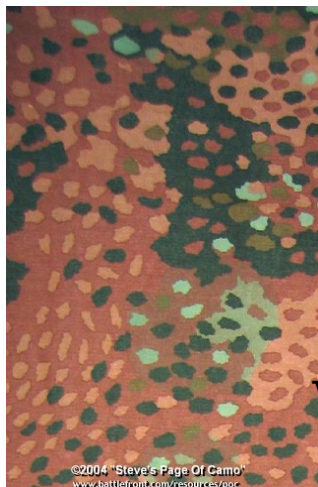
<http://www.strategypage.com/gallery/articles/friendlyfire.asp>



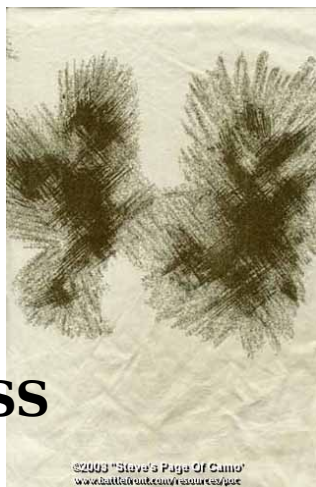
II. REDUCE DETECTABILITY



SOLDIER CAMOUFLAGE



GE
WW II
Waffen SS



GE



SWISS



AUS
GE



GE
Desert



<http://images.google.com/imgres?imgurl>

www.battlefront.com/resources/poc/poc_images/full/westgerman7.jpg&imgrefurl=http://www.battlefront.com/resources/poc/poc_centraleurope.html&h=489&w=320&sz=26&tbnid=yiX1S27g2O8J:&tbnh=126&tbnw=83&prev=/images%3Fq%3Dflecktarn%26hl%3Den%26lr%3D%26ie%3DUTF-8%26oe%3DUTF-8%26sa%3DG

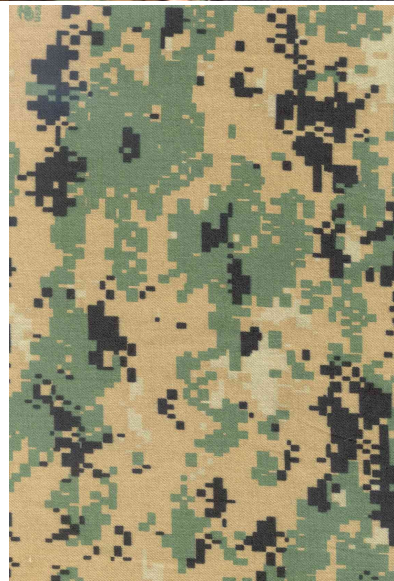


SOLDIER CAMOUFLAGE

GHILLIE (US)



DIGITAL (USMC)



FLECKTARN





SOLDIER CAMOUFLAGE



GB - Iraq (Sense of Humour)



New US



US - Iraq
Chechnya



RU - 18



DIFFICULT TO HIDE: THERMAL WEAPON SIGHTS

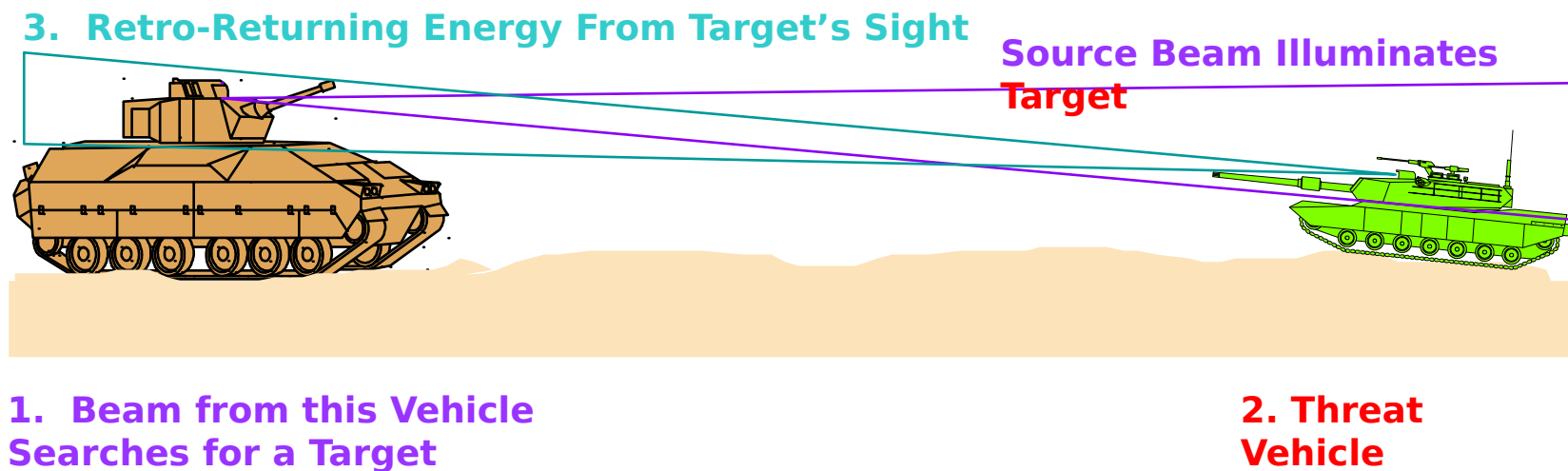




LASER OPTICAL AUGMENTATION DETECTION



- **Military Use of the Optical Cross-Section of an O/EO Device for Precise Location of the O/EO Device and Device's Platform (Targeted Device Below is on Tank)**
- **OA Refers to Illuminating an O/EO Device with Laser Energy and Using Retro-Reflected Laser Energy From the Device to Detect and Locate the O/EO Device**





ABOUT OA

- **Broad-Beam Laser Used to Sweep Horizon Along With Sensitive Device to Detect Reflection of the Laser Beam by Military Optical/Electro-Optical (O/EO) Devices.**
- **Detection Will Reveal Precise Location of Any Detectable Device (Pointing Somewhat in Direction of Laser Broad-Beam Scanner).**
- **Detectability of User O/EO Device is Dependent Upon Range of Detection and Other Factors.**



LASER VULNERABILITY INVESTIGATION



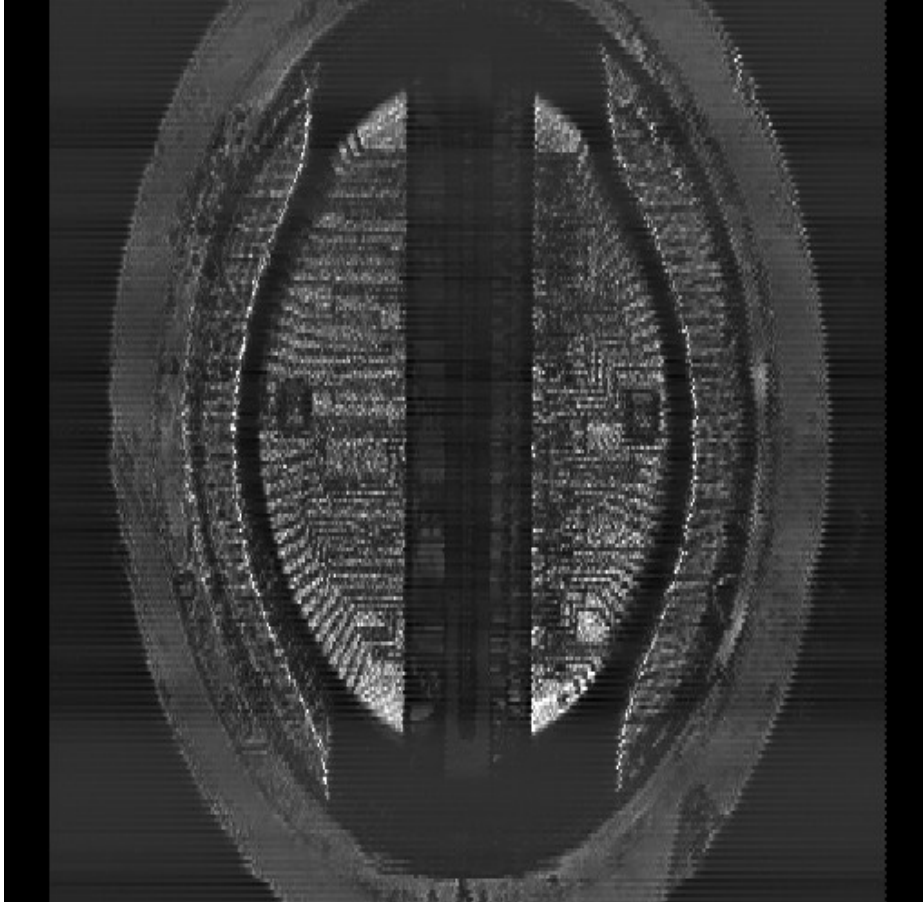
OA analyses will determine the level of susceptibility of optical/electro-optical subsystems to detection using OA techniques and will:

- **Determine the level of OA signature to verify specification compliance**
- **Determine offending surfaces within the optical train to permit additional hardening recommendations by**
 - **Generating a high resolution (128x128 samples) map of OA vs. interrogation angle**
 - **Comparing the map to engineering drawings and photographs of optical components**
- **EOVAF Visible/near-IR measurement station 10 to 100 times more sensitive than typical OA specification**

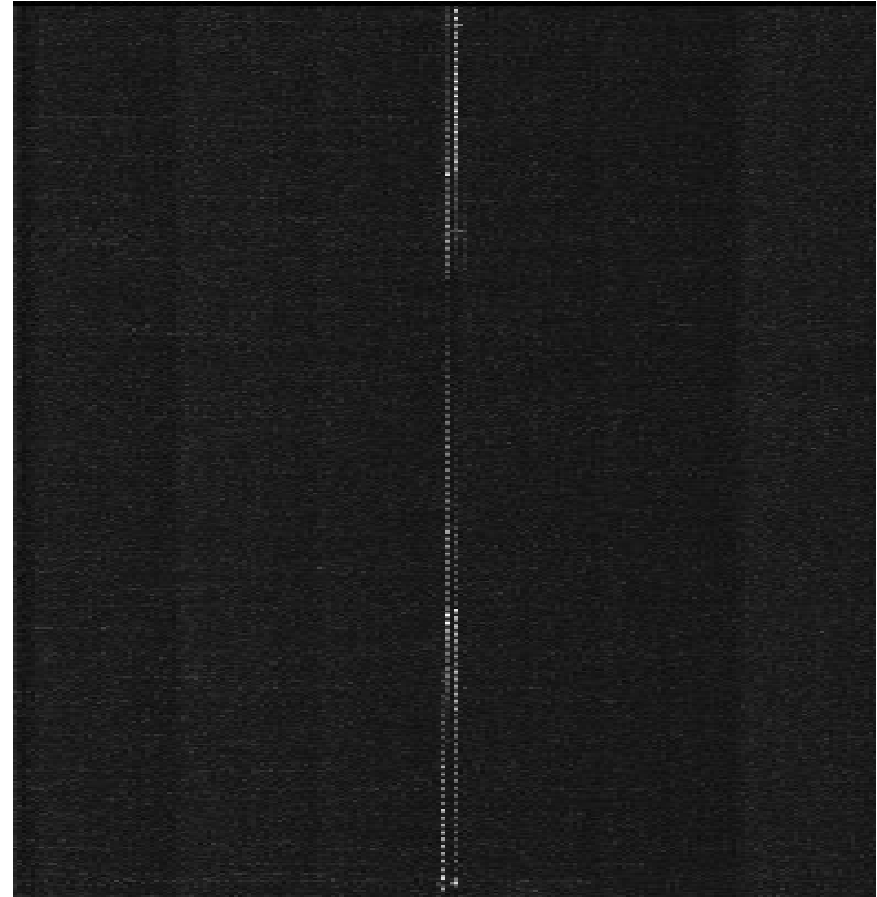




OPTICAL AUGMENTATION MAP of FLIR - BEFORE & AFTER



Unimproved



Improved



III. REDUCE PROBABILITY of BEING ATTACKED



INFORMATION OPERATIONS THREAT EFFECTS

COMPROMISE of DATA - Gaining Access to Sensitive or Classified Information Stored or Transmitted Within an Information System. (e.g. WWII: British COLOSSUS vs. German ENIGMA codes; American MAGIC vs. Japanese codes - "AF" - Battle of Midway)

CORRUPTION of DATA - The Modification of Electronically Stored, Transmitted, or Processed Information so that it Becomes Misleading or Worthless.

DISRUPTION OF OPERATIONS - Inflicting Damage or Causing Delay (Physical or Electronic) to the Systems so They no Longer Function as Designed, Thereby Effecting Denial of Service.



SECURITY TOOLS, EXPLOITS and VULNERABILITIES DATABASE (STEV dB)



- Initially developed as ARL-SLAD Tool to assist analysts.
- CIO/G6 funded expansion to fulfill needs of wider Army materiel development community.
- The database currently contains information on **over 3000 tools and/or exploits** and **over 4800 vulnerabilities**, and it is growing daily.
- Provides easy access to linked security tools and vulnerabilities.
- CONOPS has been reviewed by PMs & PEOs.
- **Ready to go on-line.**

**VIRUS
WORM**

MALICIOUS CODE



ELECTROMAGNETIC ENVIRONMENTAL EFFECTS COMPONENTS

- Electromagnetic Radiation Hazard
- **Electromagnetic Pulse**
- Lightning
- Electromagnetic Compatibility
- Electromagnetic Interference
- **Static Electricity Discharge**



Nuclear
Explosive



Fuel-Air



**Electrostatic Discharge or Cell
Phone - Potential Fire at Gas
Pump**



E3 - USS FORRESTAL

(Suspected Electromagnetic Incompatibility)



Photo # KN-4507 USS Forrestal underway, 31 May 1962



1967



Missile + Flames + Bombs



Accidents Still Occur28

<http://www.chinfo.navy.mil/navpalib/ships/carriers/histories/cv59-forrestal/forrestal-fire.html>



IV. MINIMIZE DAMAGE



RESULTS OF INFERIOR EQUIPMENT

WW II - American 3rd Armored Division Losses - Normandy Invasion to VE Day (11 mos.):

- Entered France with 232 **Sherman** Tanks.
- By VE Day Had Lost 648 **Sherman** Tanks Destroyed and Had 700 Knocked Out of Action and Repaired.
- Nov 16, '44, Combat Command B Went Into Action With 64 **Sherman** Tanks => 48 Were Hit and Put Out of Action in 26 Minutes. Same Day 2nd Armored Division Lost Almost 100.



Sherman
USA

"**Ronson**"

"**Tommy**"

- **Cooker**"

Tiger
Germany

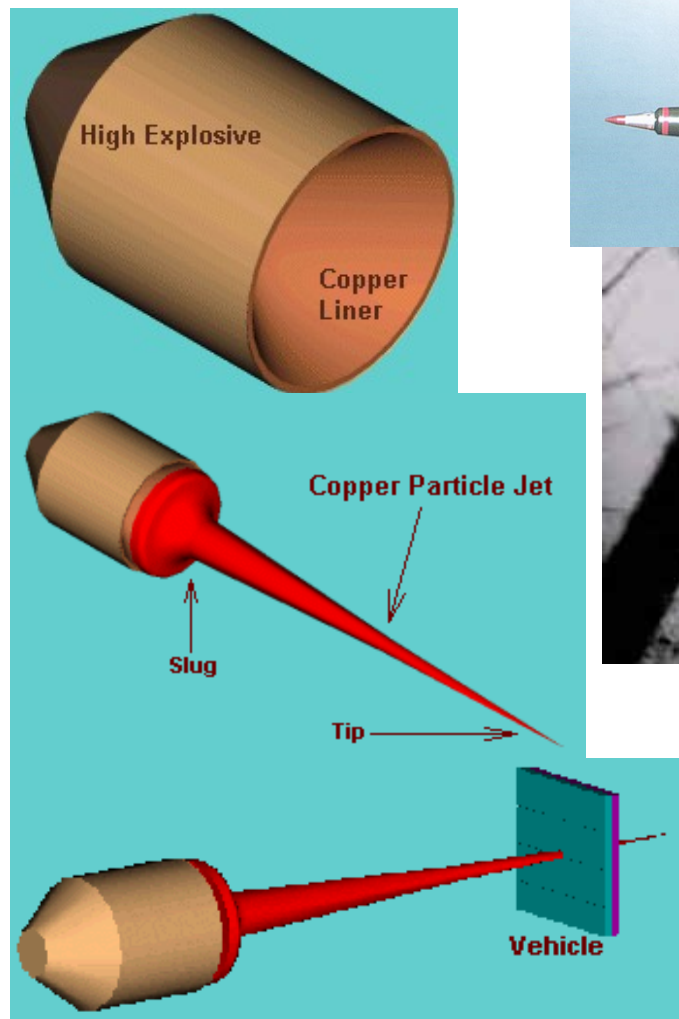


Panther
Germany

Death Traps: The Survival of an American Armored Division in World War II, by Belton Y Cooper,



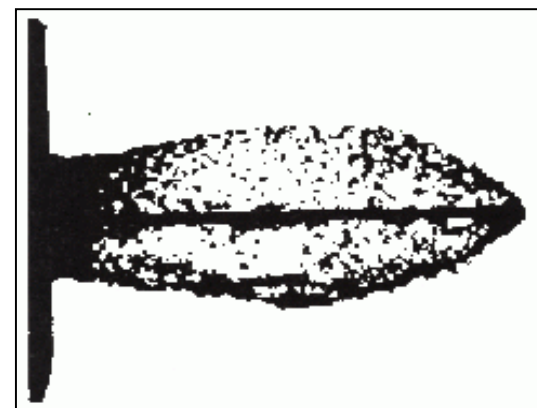
SHAPED CHARGE WARHEAD CONCEPT



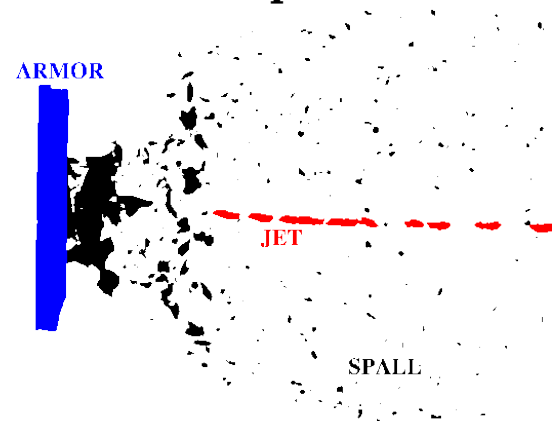
RPG-7



German
Panzerfaust
1944



Shadowgraphs of Jet &
Spall



Damage - Observation

Cupola

Ft. Eben Emael,

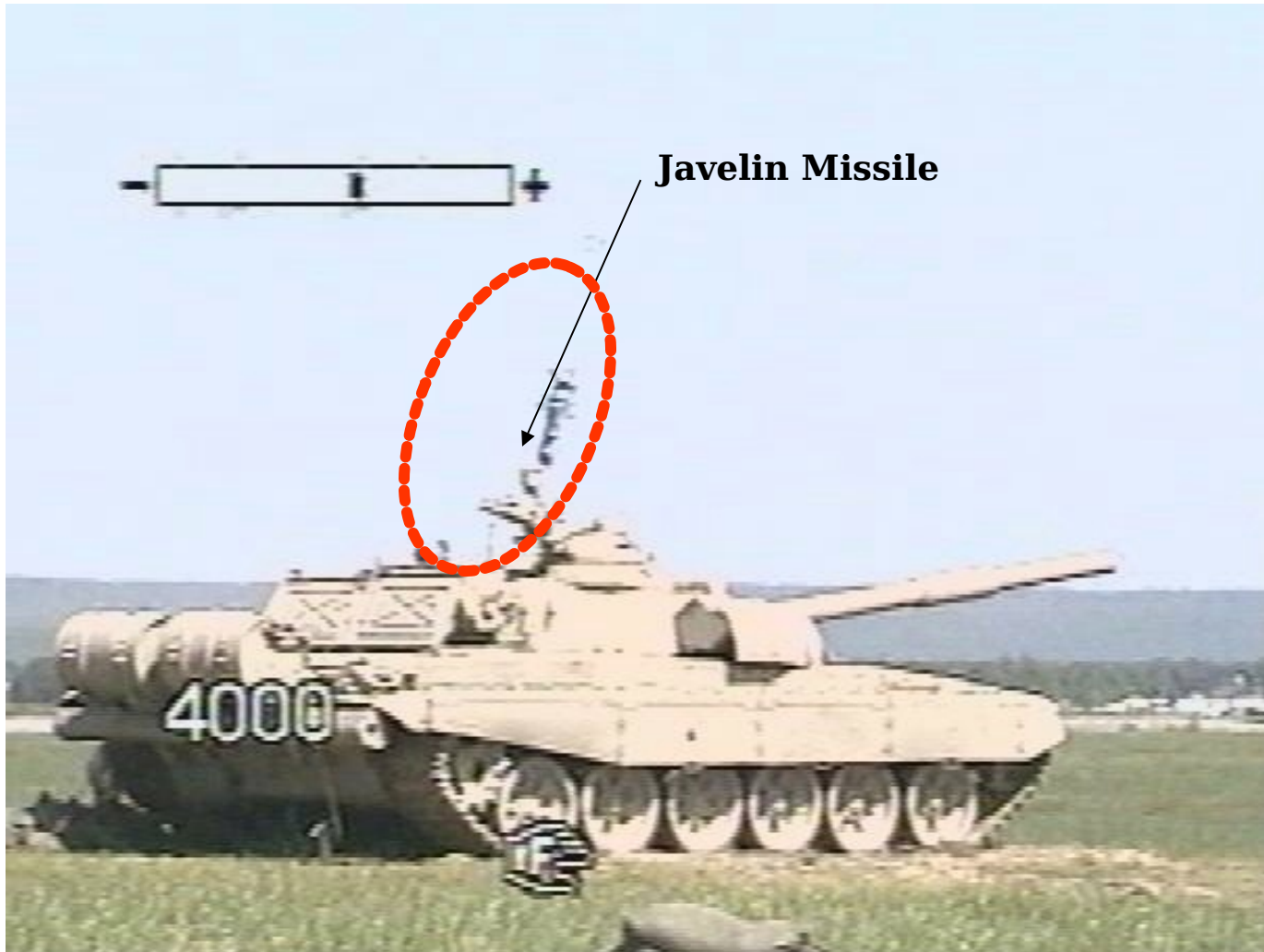
Belgium, 1940



JAVELIN FIRING AT FULLY-TACTICAL T-72 TANK



-BEFORE-





JAVELIN





JAVELIN, ALSO





WEAPON-TARGET OVERMATCH



-AFTER-





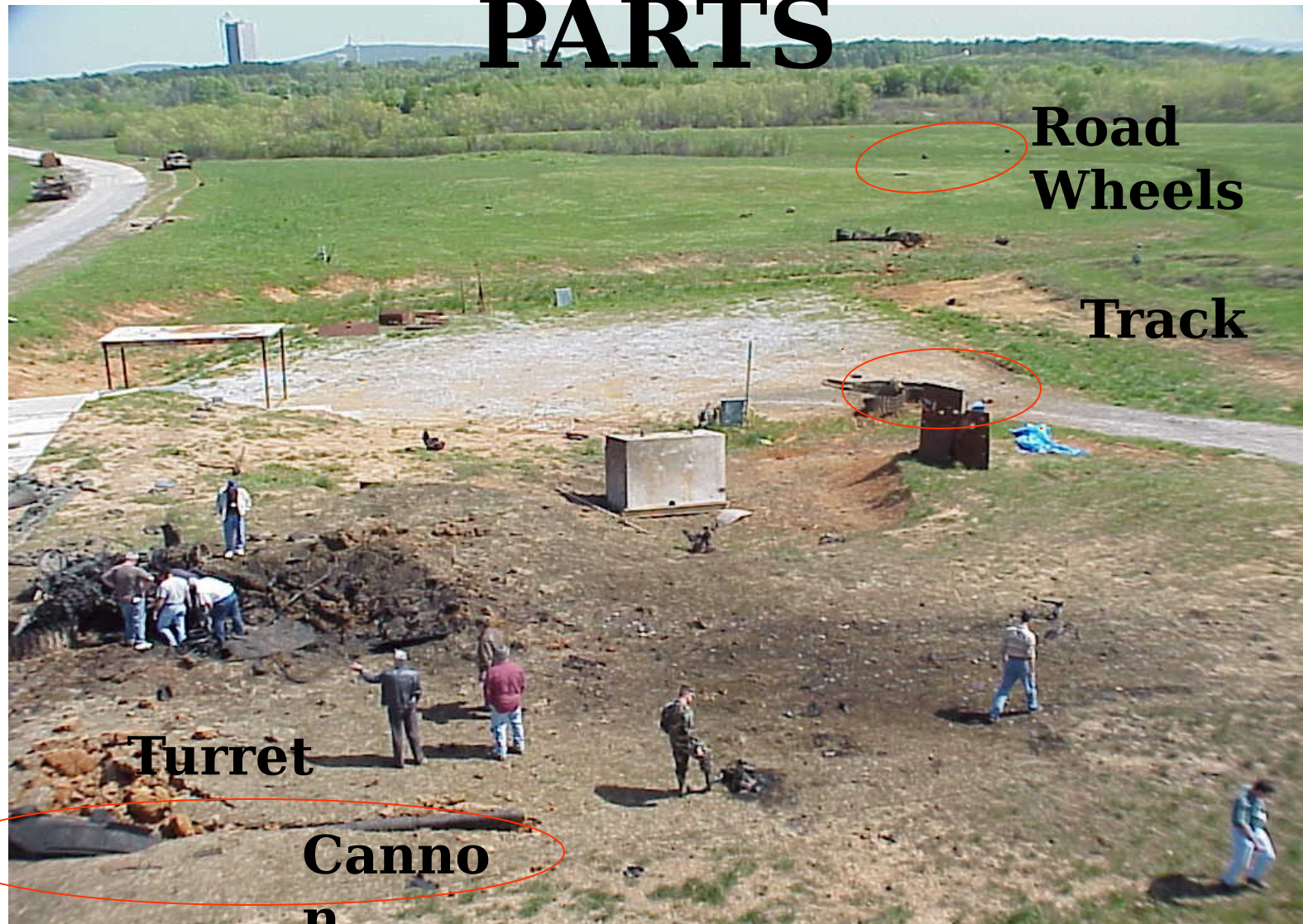
THE HULK

RESULT OF PRIMARY ATTACK AND SECONDARY EXPLOSIONS





SCATTERED PARTS



**Road
Wheels**

Track

Turret

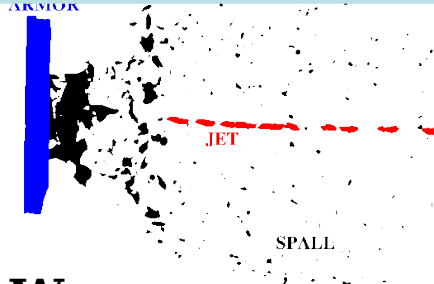
**Canno
n**



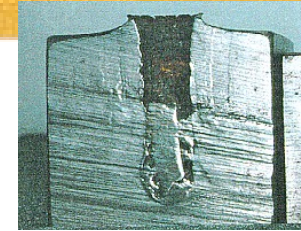
PARALLEL MODEL & EXPERIMENTAL PROCESSES



1. Characterize Target/Threat Interaction

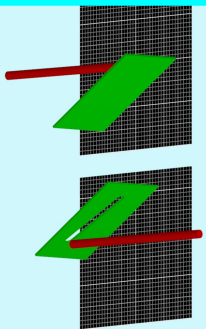


Long Rod Penetrator



Shaped Charge Weapon
Shadowgraphs of Jet & Spall

2. Characterize Damage Mechanism

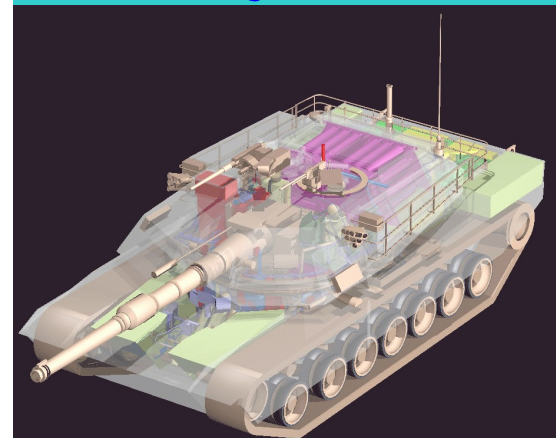


Spall Simulation
Behind-Armor
Debris/Fragments



ERA Penetration
Model

3. Construct 3D Solid Geometric Model of System





LIVE-FIRE TEST & EVALUATION



**USS OSPREY (minesweeper) at
APG, MD**





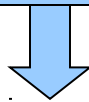
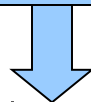
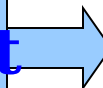
DAMAGE MECHANISM CHARACTERIZATION:

“Secondary” Damage Mechanisms

Sho



**Characterize
Target/Threat
Interaction**



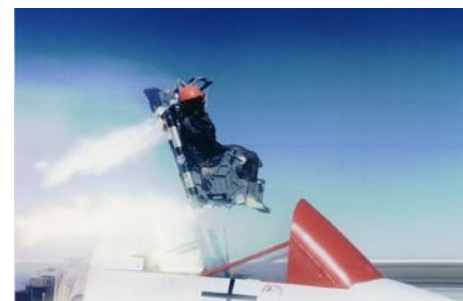
Fire - Fuel and Ammo



Bla



Crew



Challenges for Increasingly Important “Secondary” Damage Mechanisms:

- **Shock Effects on Electronics and Robotic Components**
- **Blast Effects on Light-Weight Structures, Composite & Laminate Materials**
- **Crew Acceleration Protection from Blast (e.g., Land Mines, High-Explosive Blasts Near Light Vehicles) and Impacts by Large KE Penetrators, Especially Those Damaged by Active Protection Systems**
- **Fuel Fires & Ammunition Reactions (e.g., Fire Initiation/Sustainment, Compartmentation)**



WARTIME PROOF OF SUCCESS



**No Loss of Life in ABRAMS
Tanks During Operation Iraqi
Freedom**

http://www.strategypage.com/gallery/default.asp?target=abrams_lessons_learned.htm



**BRADLEY (1
photo)**



V. MINIMIZE INJURY



1994 German Gran Prix
12 seconds



Dale Earnhardt, JR. 2004

Associated Press Photo

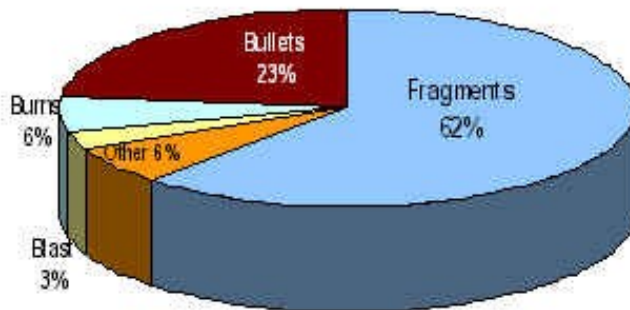


CAUSES AND ANATOMICAL DISTRIBUTION OF WOUNDS

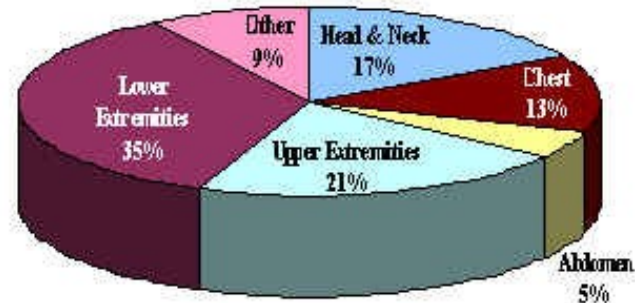


COMBAT WOUNDS

Wound Causes



Wound Distribution



WWI, WWII, Korea, Vietnam, Middle East

- SOURCE:
- Helmets & Body Armor in Modern Warfare, B. Dean, Yale Univ. Press, 1920
 - Battle Casualties, G. Beebe Atal, C. Thomas Publ., 1952
 - Wound Ballistics, Office of Surgeon Gen., 1962
 - MLRR 257 (AD 29480), 1954; 144 (AD B954368), 1952; 221 (AD28447), 1953
 - WDMET, EASP 100-67, Vol 3, 1969
 - MED Bulletin of the US Army, Europe, Vol 35, No. 8, Nov/Dec 1978
 - USAIA 2201 1129 77, 1977
 - WSEG 237, Vol 3, Part 3, 1975
 - ISRAELI Journal of Med. Sciences, Vol 20, 1984

SOLDIER SURVIVABILITY **BEYOND THE OBVIOUS**

Example - Usage of “Chemical Agent Man” Model (Effects on Body Systems):

- **MOPP IV Heat Stress and Body-Weakening Effect Before Chemical Attack - Not Considered.**
- **Hot Desert Environment - Soldier’s Dehydrated State - Not Considered.**
- **Soldier May Have Taken Pyridostigmine as a Prophylactic to Chemical Exposure - Not Considered.**
- **Pyridostigmine Causes Soldier to Have a Hard Time Aiming His/Her Rifle to Protect Himself - Not Considered.**
- **Atropine as Antidote for Chemical Attack Injury in Hot Environment - Will Stop Soldier’s Sweating Mechanism and Probably Kill Him from Heat Stroke - Not Considered. (Being Addressed.)**



COMBAT STATISTICS



<http://www.strategypage.com> April 2004



- **INTERCEPTOR** Protective Vest - **ONLY 9% of Combat Wounds to 118 Army Casualties Were in the Trunk.**



- **Autopsies of 154 Soldiers - Most Common Area Hit Was Head - Neck and Face.**

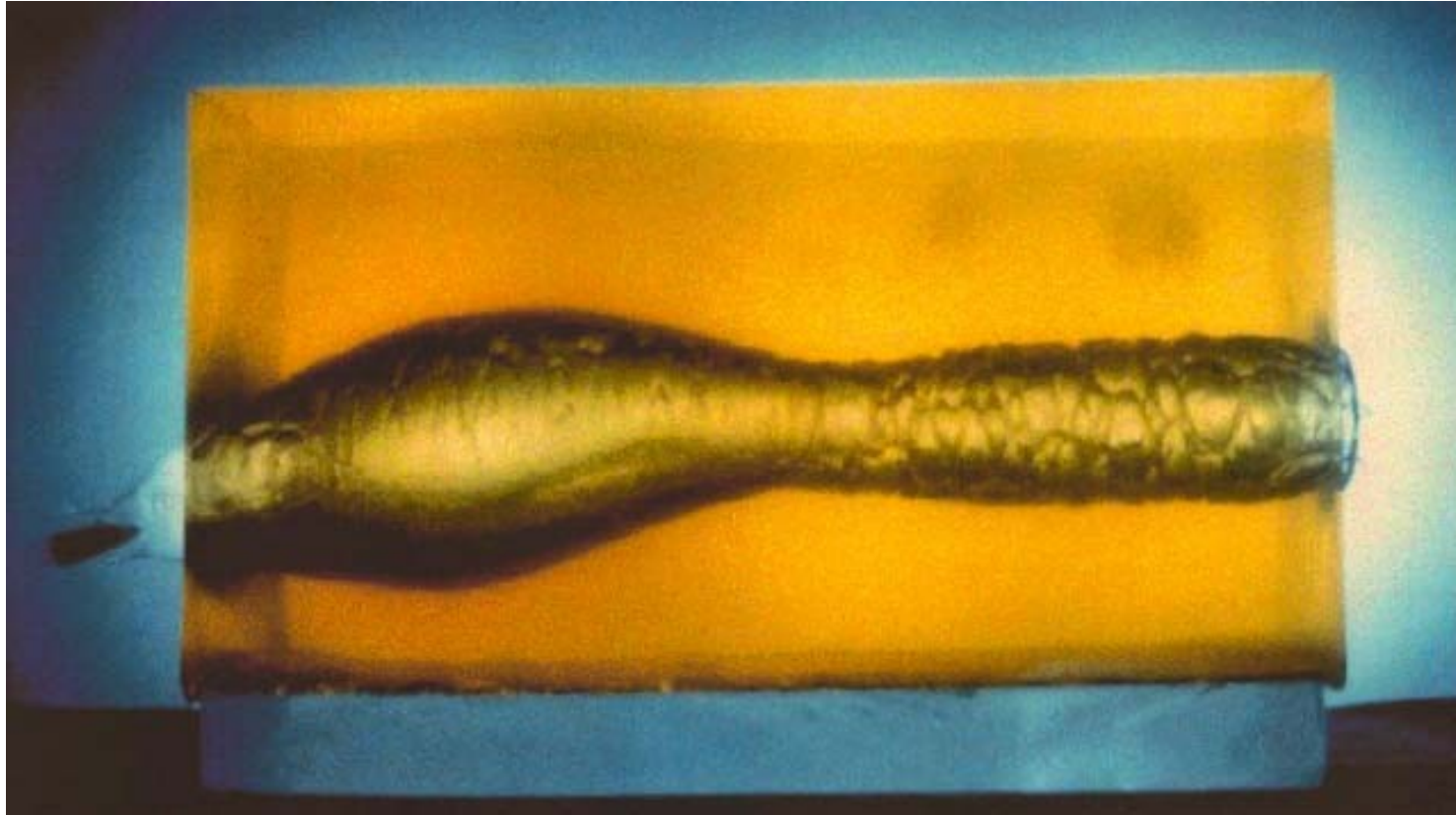


- **Iraq Average Range of Engagement for Infantry - 20-30 Meters; Snipers - Less than 300 Meters.**

SPECWARGEAR.COM



SMALL ARMS & FRAGMENTS

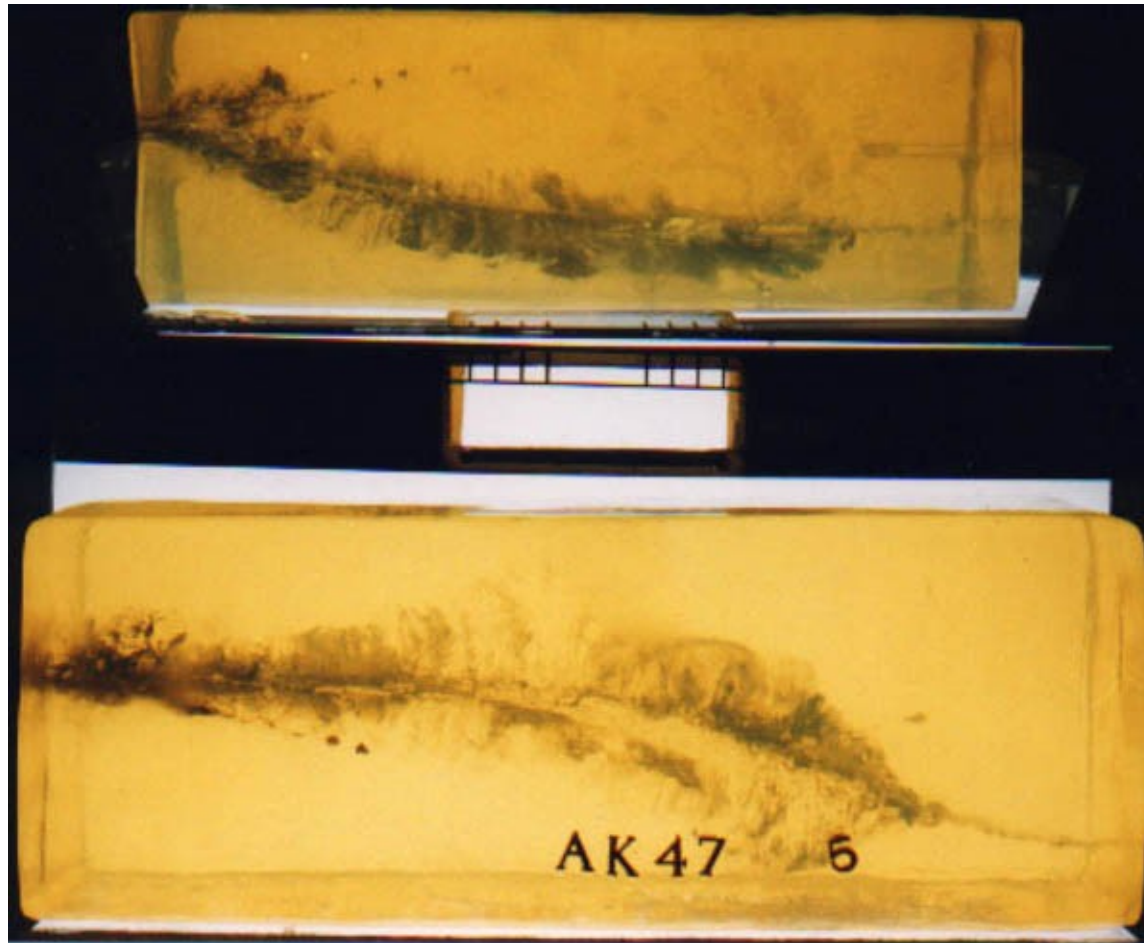


**BALLISTIC GELATIN
(4"x4"x20")
AMMO
CHARACTERIZATION**



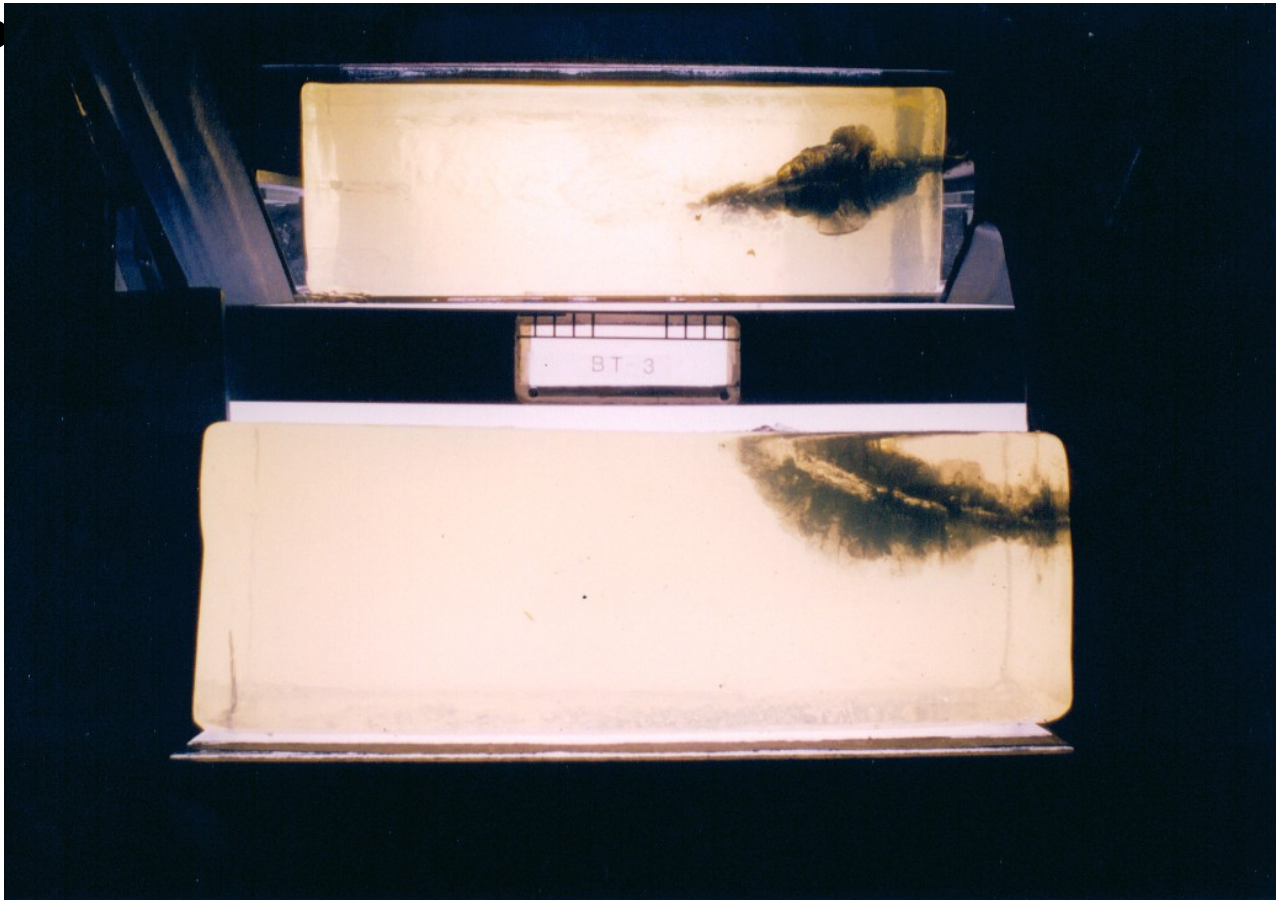
BALLISTIC GELATIN

AK-47



SOLDIER SURVIVABILITY PAL ISSUE EXAMPLE

- Does the System Carry Anything Other Than Ammunition That Could Be Volatile or **Toxic** in Co





EXTINGUISHING VEHICLE FIRES



Example:



By Volume:

25-60%

10-

Extinguish Flame

120%
Breathing



SOLDIER AND EQUIPMENT SURVIVABILITY ASSESSMENT

- **Naval General Survivability**

Definition: Ability to Exist and Function Through and After Exposure to Hostile Situations and Environments.

- **Army** Viewpoint is Primarily Affected by Combat on Personnel and the Equipment They Operate.



AERIAL WATER HAZARDS



<http://www.informationclearinghouse.info/article4176.htm>

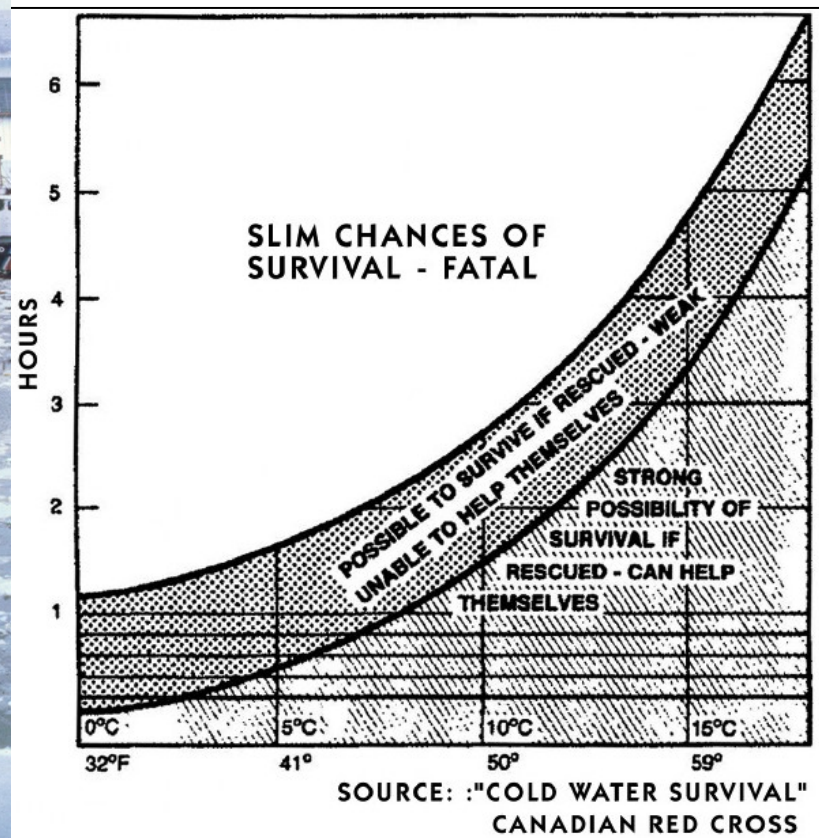
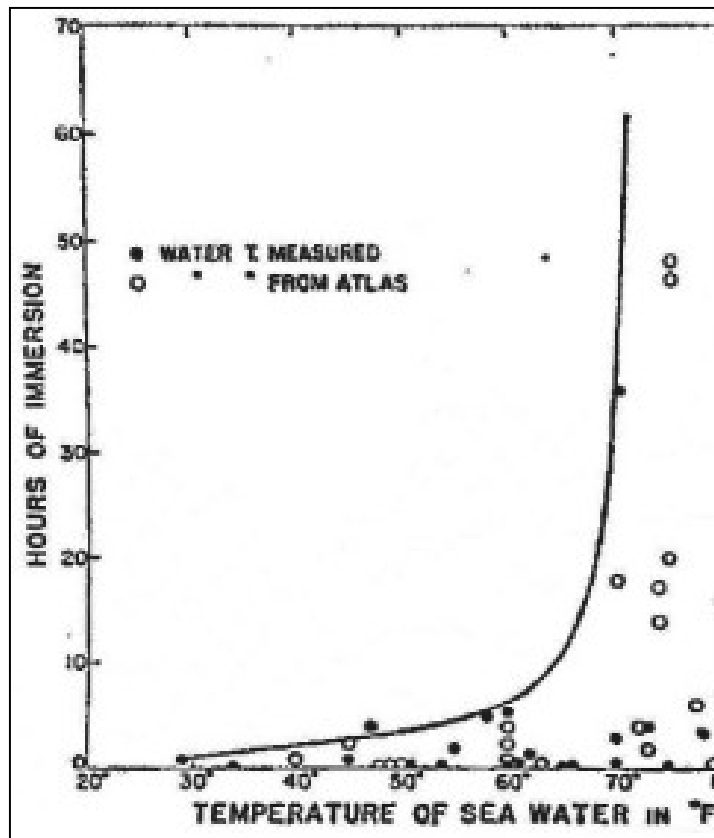
BLACKHAWK - IRAQ



<http://www.sims.berkeley.edu/~aragon/thesis.html>



IMMERSION SURVIVAL IN VARYING WATER TEMPERATURES



Heat Loss: 25x Faster for Skin to Water, than

for Skin to Air
Air Florida 90, 14th Street Bridge, Washington,
D.C. January 1982



SOME AVIATOR SSv ISSUES



- Critical
 - Helicopter Crash in Water - Underwater Escape From Helicopter



Photo by REUTERS/John Heber



<http://www.aircav.com/kosovo/ah64crash/ah64crash.html>



- Major
 - Escape & Evasion on Ground - What to Take? - Inability to Carry Water Supply (**Altitude**)

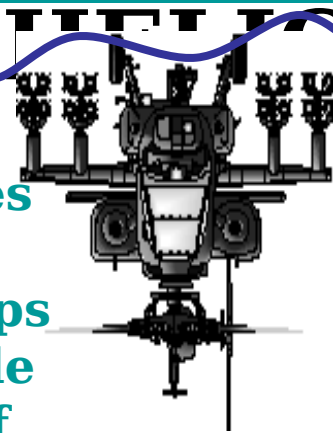


AVIATOR UNDERWATER EGRESS FROM



Surface

Engine(s)
Location(s) Causes
High Center of
Gravity Which Flips
Helicopters Upside
Down in Bodies of
Water



Surface



Surface

Surface

Surface

Surface

Surface

Surface

Surface

Problems With:

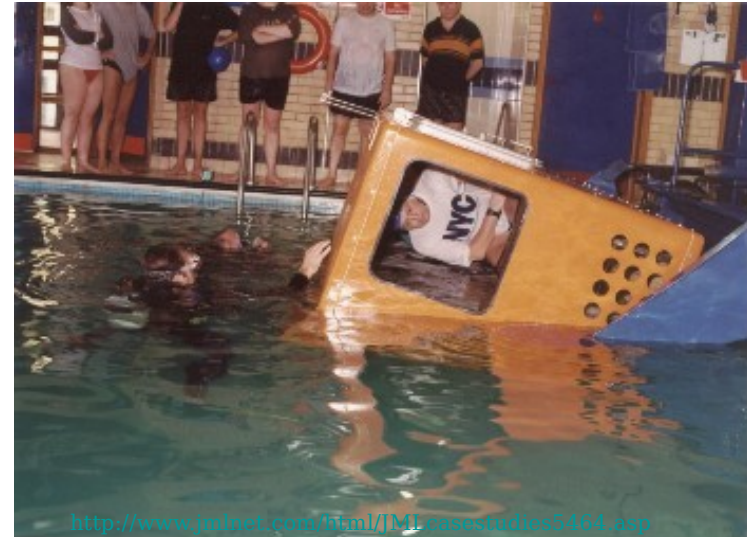
- Disorientation/Darkness
- NBC Mask Removal
- Activating S.E.A.
- Disconnecting Straps & Cables
- Opening Exits



Cockpit Roof



HELICOPTER WATER SURVIVAL TRAINING



<http://www.jmlnet.com/html/JMLcasestudies7464.asp>



COBRA
Pilot
USMC
UK AR5
NBC
Mask
Tear-Away
Face-Plate



http://public.srce.hr/ak_zagreb/Cobra/ah1w/



UNDERWATER HELO EGRESS



• Requirement: **TESTS**

- Aviator In **MOPP IV** Must Escape From
Inverted Helicopter 20 Feet Below
Water
Surface
- Use “Survival Emergency Air” (SEA)
To Reach
Surface
- Inflate Life Preserver And Rise To
Surface In



UNDERWATER EGRESS



SSv FINDINGS

Findings:

- SEA Will Only Provide **30 Seconds Air At Rest**
When At 20 Foot Depth Instead of 5 Minute Supply
- Selected Life Raft Would Only Be Fully Inflated Above 55° F Seawater
 - Requires Human Ventilation To Fully Inflate
 - Injured or Semi-Conscious ? => Partially Inflated Raft May Cause Human Body Heat Storage Crisis.



SME ISSUE

- LESS THAN OBVIOUS -



**HELICOPTER AVIATOR
NBC MASK AT ALTITUDE**

**(Rescue or Operations at 14,000 -
20,000 Feet)**

**NBC FILTER CANISTER WITH
CHARCOAL ELEMENT**

+ OXYGEN REQUIREMENT

= FLAME



JOINT MODULAR LIGHTER SYSTEM



FLOATING CAUSEWAY



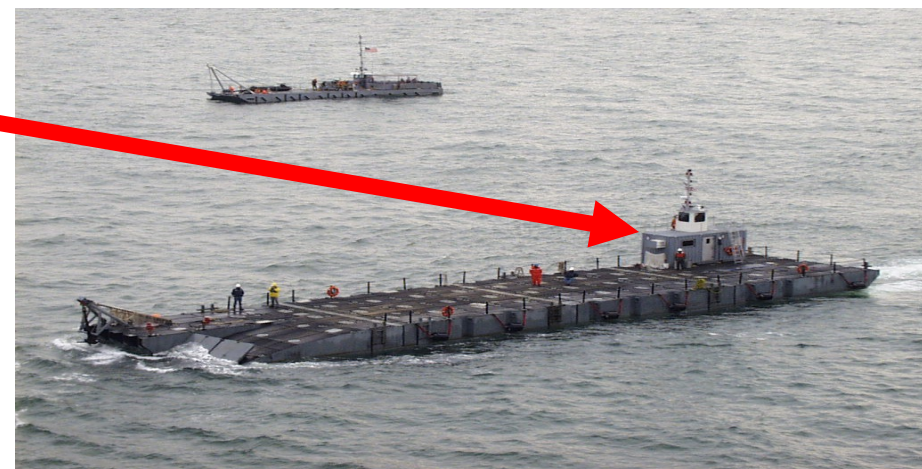
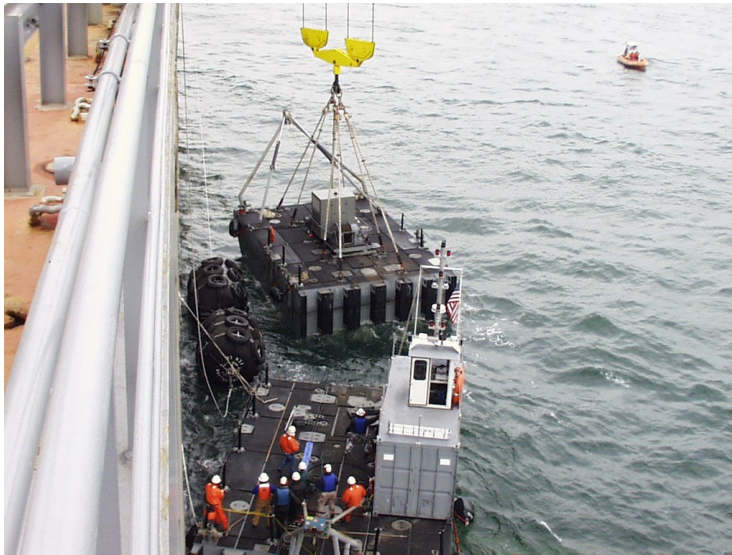
2/22/2000

[http://chl.erdcl.usace.army.mil/CHL.aspx?](http://chl.erdcl.usace.army.mil/CHL.aspx?param=MEDIA-76)

param=MEDIA-76



JOINT MODULAR LIGHTER SYSTEM





SOME JMLS ISSUES



- **Falling Overboard** - No Way to Get Back On Board.
- **Potential Entrapment in Shelter** - Negative Pressure Build-Up When Head Electric **Incinerator** (1000 deg. F.) is Activated - Functional for 2 Hrs Before Another Person Can Use It. **47 cubic ft/min Deficit** - Within 7 minutes Reduces Pressure at Sea Level to Equivalent of 10,000 Ft. Altitude. Extremely Difficult to Push Door Outward to Leave Unless Break Window.
- **Assembly** - Crewmember Can Lose Balance and Fall Between Modules to Be Crushed, or to Fall Into Sea at Low Sea States.
- **Wash Overboard** - In Sea States 2 and 3, a Crewmember Can Slip and Be Carried Over the Side by “Green” Water Washing Over the Deck. ⁶¹



MINIMIZE INJURY - EMERGENCY EGRESS -

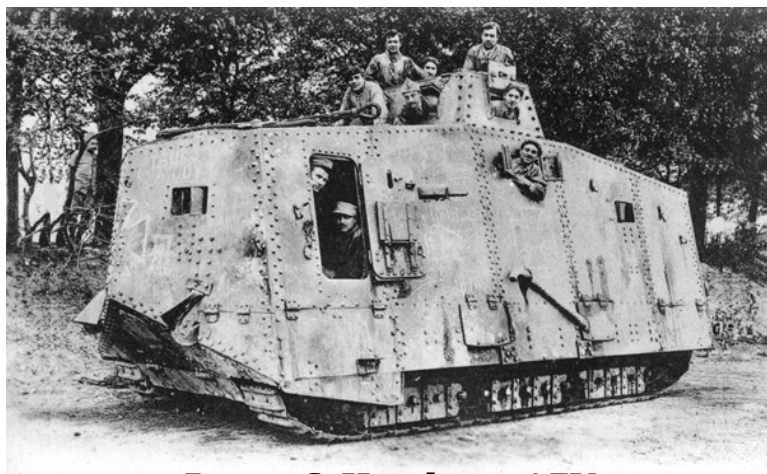


194
0 200
4
Open
Top
Until
Proximi
ty Fuze
for
Overhe
ad Air
Burst





PRIOR EGRESS



**Doors & Hatches - A7V
Germany WWI**



Hatches PzKfw III - WWII (Hull Strength)



Hatches - Panther WWII



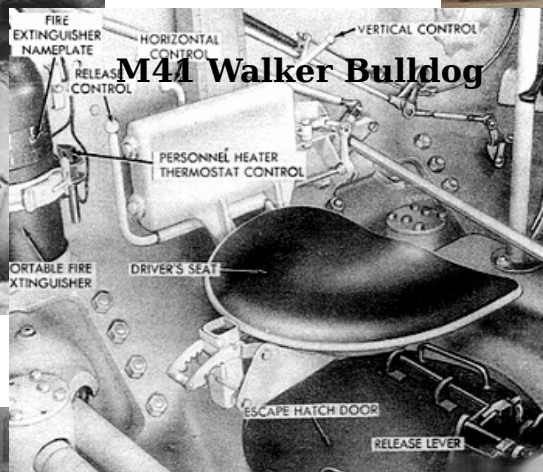
Hatches & Doors M3 Lee - WWII



HULL ESCAPE HATCH



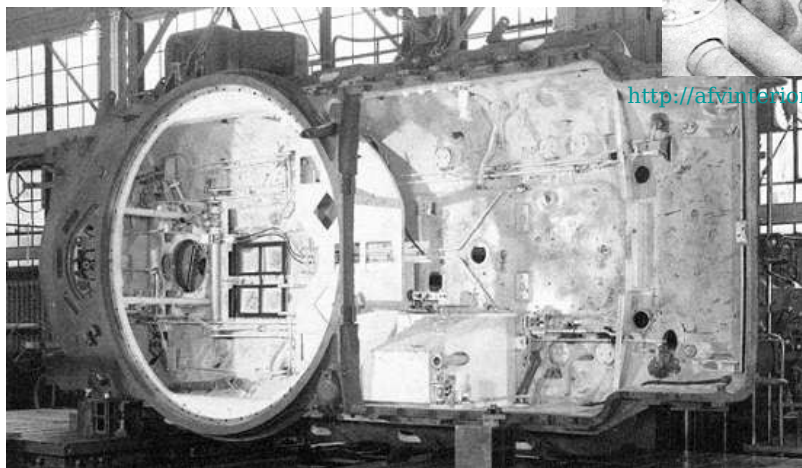
- M4
SHERMAN -



M41 Walker Bulldog

<http://afvinteriors.hobbyvista.com/m4fac/m4fac3.html>

<http://afvinteriors.hobbyvista.com/m48/m48a.html>



- M48 PATTON -





DESIGNER - REALIZE

ESCAPING TRAINED CREWMEN BECOME TARGETS



<http://www.ttjstk.myrice.com/wqxh/mkw%20tank/merkava12.jpg>



VI. MINIMIZE PHYSICAL AND MENTAL FATIGUE



NBC



VOLUME:

20 l/min Sinusoidal (breathing in & out)
30-55 l/min Sinusoidal (light to moderate exertion)
240 l/min Sinusoidal (max. exertion)

SPEED OF FLOW:

85 l/min (just one direction flow; e.g. exhalation)
900-1400 l/min (required at max. exertion)





COMBINED ARMS IN A NUCLEAR/CHEMICAL ENVIRONMENT (CANE) 1 RESULTS



Units - PLATOONS (MECH INF)
1987

Operation Time - 72 Hours

- **Majority of Soldiers Were Clinically Dehydrated.**
- **In Direct Fire Battles:**
 1. Increase in Casualties Per Enemy Attack.
 2. Larger Percentage of Soldiers Required for Successful Attack.
 3. Large Percentage of M16 Friendly Personnel.
- **Communications About Half as Effective**
 1. Disorientation
- **Teamwork Inhibited:**
 2. Frustration
 3. Irritability



Gas Mask Training



"Charades" May Work Better ..

Syllables: 1st - may not be heard; 2nd - can hear;
3rd - slurred?



THEATER SUPPORT VESSEL



CATAMARAN HSI HABITABILITY

- ACCORDING TO CUSTOM -



**SKIPPER'S
BRIDGE**



ARMY HALF OF CATAMARAN



NAVY HALF OF CATAMARAN



SUMMARY

- **Soldier Survivability Focuses on the Soldier, as the Equipment Assists Him or Her in Performing the Combat Mission in a Battlefield Environment.**
- **HSI/MANPRINT SSv Domain Is Now Recognized Within U.S. Army Acquisition, and by Outside Organizations.**



SOLDIER SURVIVABILITY

- CONTRIBUTING TO SUCCESS -



<http://www.armytimes.com/channel.php?QID=show>